Bull. Natn. Sci. Mus., Ser. A (Zool.), 3 (1), March 22, 1977

The Systematical Position of *Sinentomon* (Insecta, Protura)

By

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(Communicated by Yoshinori IMAIZUMI)

In 1965 Dr. W. Y. YIN published the description of a proturan which was entirely different from any proturan hitherto known. She gave it the name *Sinentomon erythranum* and regarded it, since it had spiracles and tracheae, as belonging to a separate family within Eosentomoidea. Her description was very detailed and accompanied by good drawings. She presented me with two males, two females and a so-called larva III with 11 abdominal segments, all collected by herself on June 16 and Nov. 17, 1964. It was evident that the species did not at all fit into my scheme of proturan systematics (1964) which was at that time unknown to Miss YIN.

In 1966 (p. 293) IMADATÉ published a redescription of the species and wrote that it "may be the most archaic and the most interesting living proturan known up to the present." He stated that "larva III" was in fact a maturus junior, the 11th segment being extremely reduced dorsally, but not ventrally. He did not touch upon the question of its affiliation within Protura.

In 1973 NOSEK, without adding new particulars (only citing IMADATÉ, 1966), erected a new suborder, Sinentomoidea, for the species which "shares morphological features of three different families" (p. 63). He also mentions that *Hesperentomon* is closely related to *Sinentomon*; YIN stated the similarity in the mouthparts.

In an attempt at establishing the true systematic position of *Sinentomon* which I do not regard as an archaic type but, on the contrary, as a highly specialized form, I have made a re-examination and drawings of the specimens presented to me and a re-evaluation of the characters.

I am very grateful to Miss YIN for having made this examination possible with her gift.

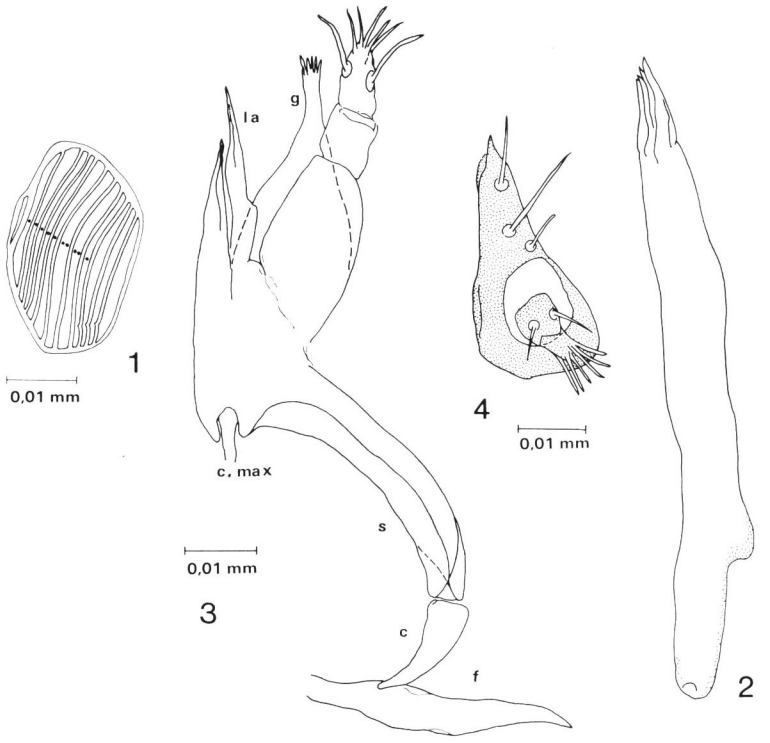
Sinentomon erythranum YIN, 1965

(Figs. 1–5, 7–14)

Cuticula very thick, distinctly coloured (yellow-brown) and with many irregular and irregularly arranged transverse rows of small spines, dorsally as well as ventrally.

Head: of normal shape, no rostrum. Setae fairly long and very strong. Pseudoculi with a grating of strong bars (Fig. 1). PR=6.5. Clypeal apodeme absent.

Mouthparts: The mandible (Fig. 2) is broad throughout its length, near the



Figs. 1–4. *Sinentomon erythranum* YIN. —— 1. Pseudoculus. —— 2. Mandible. —— 3. Maxilla; f, fulcrum; c, cardo; s, stipes; la, laciniae; g, galea; c. max, canal of maxillary gland (?). —— 4. Labium.

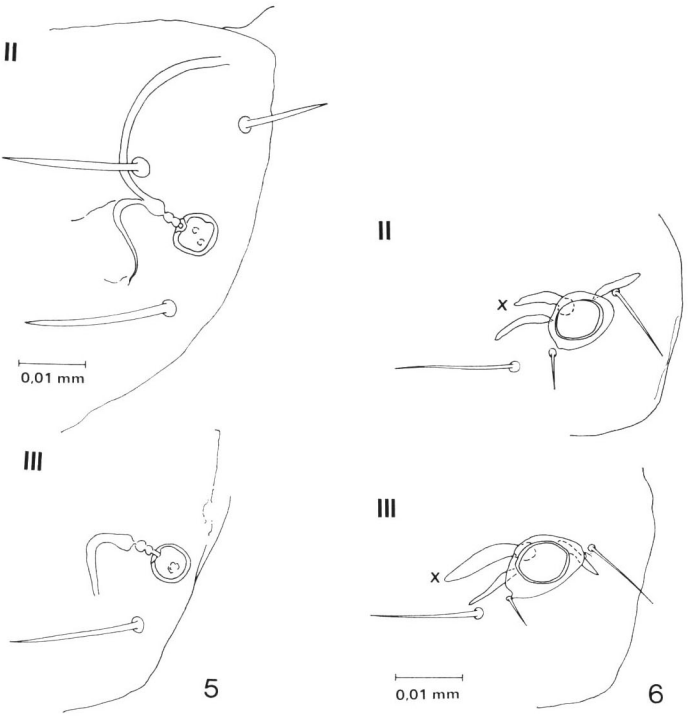
proximal end with a small dilatation. Distal end with 3–4 small teeth marked by short ridges.

Maxilla (Fig. 3) with stipes and cardo curved, the distal end of the canal of maxillary gland distinct (?), but no dilatations (calyx etc.) visible. Two pointed and strongly sclerotized laciniae and a weakly sclerotized galea ending in six lobes ("fingers"). (I use the well documented interpretations by FRANÇOIS (1969) instead of my earlier from 1964.) Palpus with three segments, two sensillae and tuft at the apex.

Labium (Fig. 4) triangular with three setae on distal part, none on the proximal. Palpus two-segmented, with two setae and end tuft. No sensillae.

Thorax: Three-segmented, heavily sclerotized, with irregular rows of spines. Dorsal chaetotaxy on prothorax consisting of 4, on meso- and metathorax of 19 setae arranged in three rows of 8, 6 and 5, comparable with IMADATÉ's scheme (1966, p. 289): 8 anterior and 11 posterior setae. There is a canal or nerve visible through the cuticula in connection with the setae; it is as long as the setae of the hind row, shorter than setae of middle row, and only very small in connection with the setae of the first row. This may be dependent on the thickness of the cuticula and holds actually true of all setae.

Meso- and metathorax with spiracles (Fig. 5). They are shaped as a cuticular ring surrounding an area of weaker sclerotization in which some indistinct structures are seen. Medially a small part of the ring is open and gives access for a trachea shaped apparently as two small chambers and a bigger proximal one from which a foreward and a hindward pointing branch (mesothorax) or only a hindward pointing one (metathorax) originate. The fate of these branches I could not follow.



Figs. 5–6. —— 5. *Sinentomon erythranum* YIN; spiracles of meso- and metathorax. —— 6. *Eosentomon transitorium* BERLESE; spiracles of meso- and metathorax. For "x" see text.

The spiracles are the main reason for inserting *Sinentomon* into or close to Eosentomoidea, the only known suborder with spiracles. For comparison I have therefore drawn the spiracles of an *Eosentomon* (*transitorium* BERLESE) (Fig. 6). It is easily seen that they are quite different. The ring on the surface is not circular, but oval and, in metathorax, broader at the ends. From this ring three "sacs" are seen descending into the interior; in phase contrast two of them are seen as distinctly hollow sacs, but the third, marked with an x, is quite different. Its drop-shaped part closest to the ring is hollow, but the rest is not. It is doubtful whether it actually belongs to the tracheal system. The fate of the two "sacs" I cannot follow, but it is well-known (BERLESE, 1909, tavola XVII, fig. 176) that they lead to two tracheal trunks which have no connection with each other longitudinally or transversely.

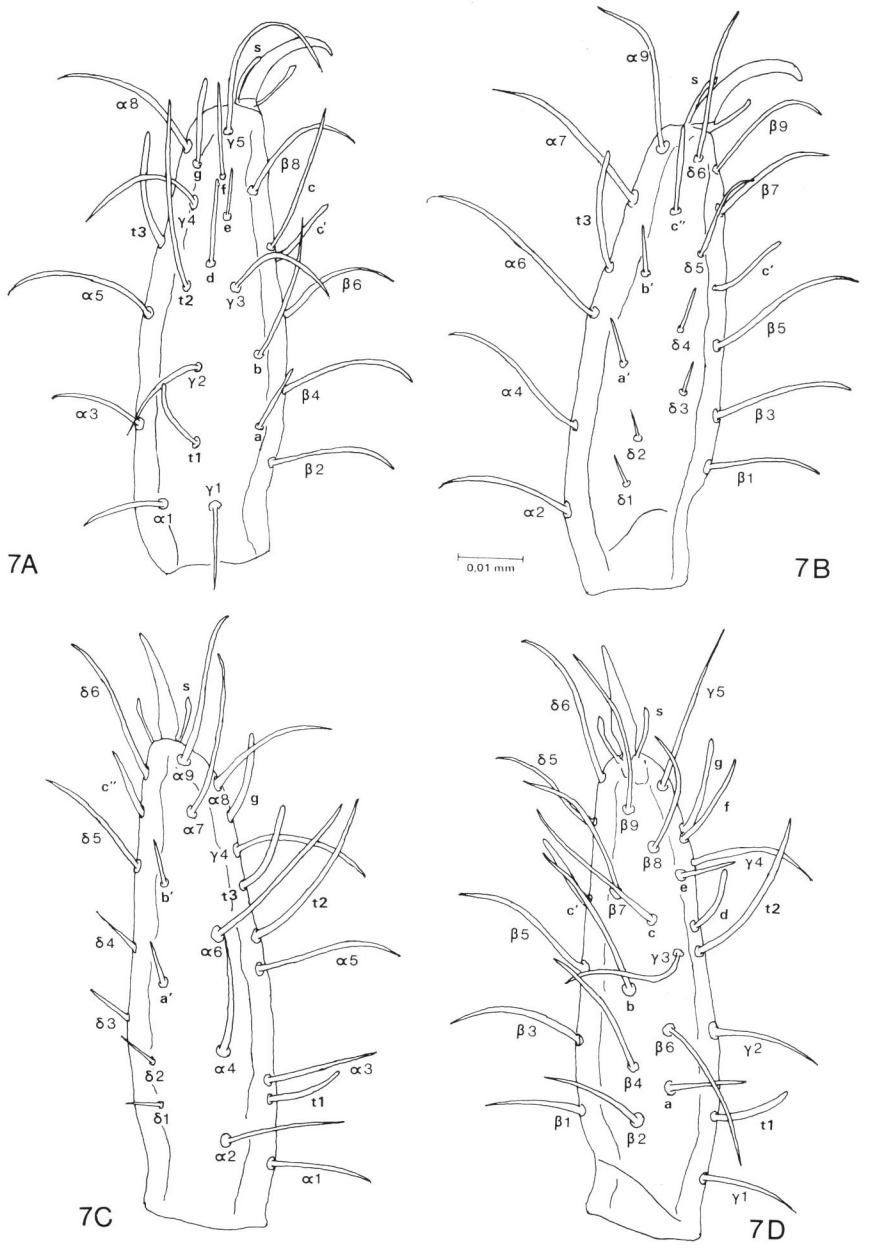


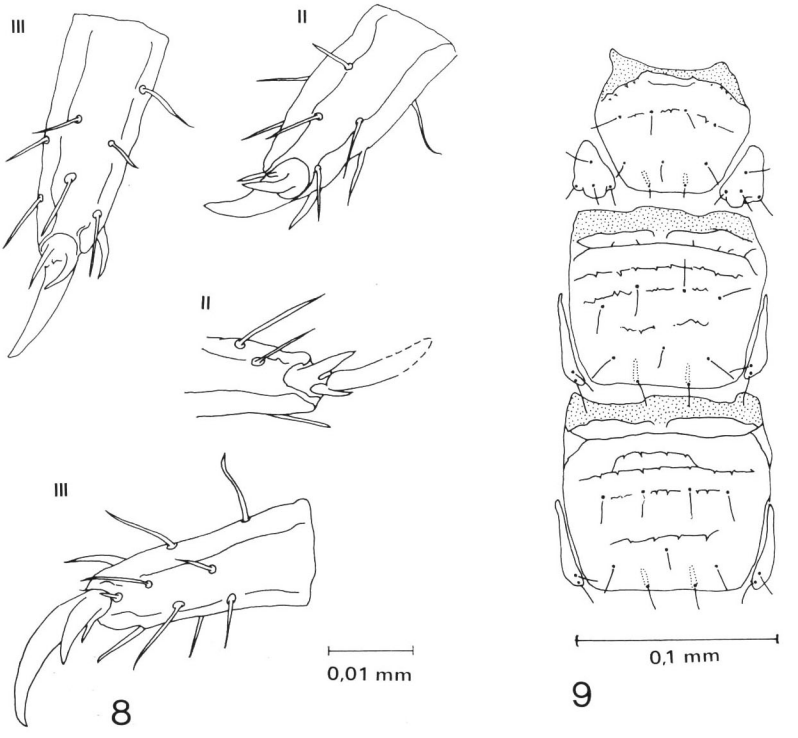
Fig. 7. *Sinentomon erythranum* YIN. Foretarsus in exterior (A), interior (B), dorsal (C) and ventral views (D).

A comparison of Fig. 5 and Fig. 6 will immediately show that the spiracles though present at the same place are completely differently shaped. It is well-known that tracheal systems are developed several, not to say many times during the evolution of arthropods; I have no doubt that the systems in *Eosentomon* and *Sinentomon* are evolved independently.

The foretarsus is depicted in Fig. 7 from the interior, exterior, dorsal and ventral side of two specimens. The setae are drawn as well as the sensillae, because some of the sensillae are seta-like, thus giving rise to doubt. This is one of the reasons why my interpretation is different from that of IMADATÉ (1966); another is that he compared the setae and sensillae with those of *Eosentomon*. In my interpretation I have had the acerentomoid picture in mind and tried to follow this; with the exception of having to add 2 α- and 2 β-setae I find I succeeded.

The foretarsi carry the following setae: 9 α-setae in a zigzag row except α 6–α 7 which are on line (Fig. 7 C). 9 β-setae in a zig-zag row (Fig. 7 D). 5 γ-setae in a zig-zag row (Fig. 7 A). 6 δ-setae in a straight ventral-pointing row as always in Acerentomoidea (Fig. 7 B).

The following sensillae are present: *t 1–3* (Fig. 7 C), *a–g* (Fig. 7 A) and *a'*, *b'*, *c'*



Figs. 8–9. *Sinentomon erythranum* YIN. —— 8. Claws of middle and hind legs in different views. —— 9. Sternum with legs of abdominal segments I–III.

and c'' (Fig. 7 B). *t 1* is thick, pointed and of medium length; *t 2* very long, slender, pointed; *t 3* long and thick, blunt; *a* is short and pointed; *b* long and pointed; *c* long and pointed; *d* of medium length, pointed; *e* short and pointed; *f* slender and pointed; *g* thick and blunt. a' and b' are short and pointed, but longer and thicker than δ 1–4; c' of medium length, blunt, ventrally to b'; c'', also of medium length, anterior to b'.

In these identifications of setae and sensillae their mutual relations agree with that of Acerentomoidea in general.

The claw is broad and strongly bent. TR=3.7. Empodium and seta *s* half the length of the claw, bent against the claw in the same way as in many Protentomidae and a little widened towards apex.

Legs: Fig. 8 shows the claw of the second and third pairs of legs in different views. The thickness of the cuticle is sketched, but the shape of the claw is important: the claw is distinctly boat-shaped, with an empodium and a short curved spine indicating the beginning of a tunica. There is a spine like that of Eosentomoidea on both second and third legs.

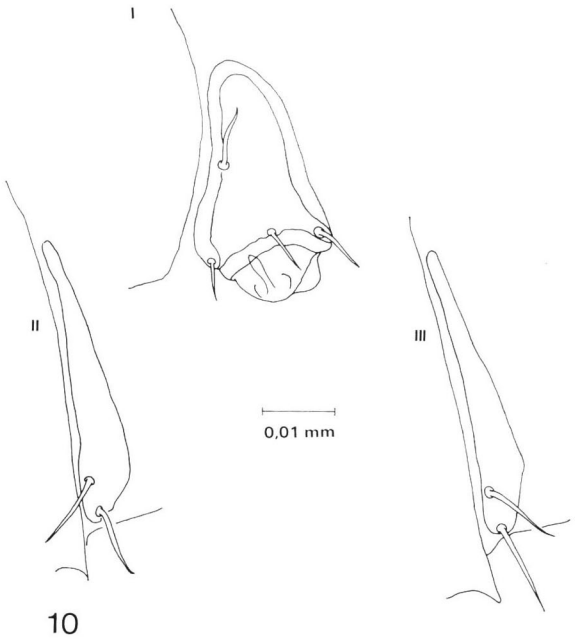


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Fig. 10. *Sinentomon erythranum* YIN. Legs of abdominal segments I–III.

Abdomen: The first three segments carry abdominal legs (Figs. 9–10) which are entirely free of the ventral sclerites. The first leg is two-segmented with a terminal vesicle and 4 setae; the leg is hollow, with a very thick cuticle. The second and third legs are solid, with two setae of equal length.

The chaetotaxy is curious in consisting of three rows of setae on both tergum and

sternum of the first seven segments. It seems reasonable, however, to regard the distal, hindmost row as the accessory setae, set free of their principal setae in the middle row and added by a central seta. In that case we get the following chaetotaxy in my scheme:

	I	II–III	IV–VII	VIII	IX	X	XI	Telson
Terg.	6/15	12/19	12/19	8/13	0/12	10	0	9
Stern.	4/5	4/5	4/7	2/7	7	7	6	8

On abdominal segments VIII–XII the dorsal and ventral sclerites are completely fused so that the distinction between dorsal and ventral setae is based on an estimate.

In IMADATÉ's scheme the chaetotaxy might be the following:

Terg.
I: a: 1, 2, 3. –p: c, 1, 1′, 2′, 3, 3′, 4′, 5.
II–III: a: 1, 2, 3, 4, 5, 6. –p: c, 1, 1′, 2, 2′, 3, 3′, 4, 4′, 5.
IV–VII: a: 1, 2, 3, 4, 5, 6. –p: c, 1, 1′, 2, 2′, 3, 3′, 4, 4′, 5.
VIII: a: 1, 2, 3, 4. –p: c, 1, 1′, 2, 2′, 3, 3′.
IX: p: 1, 1′, 2, 2′, 3, 3′.
X: 1, 1′, 2, 3, 3′.
XI: 0
Telson: 9

Stern.
I: a: 1, 2. –p: c, 1′, 2.
II–III: a: 1, 2. –p: c, 1′, 2.
IV–VII: a: 1, 2. –p: c, 1′, 2, 3.
VIII: a: 1. –p: c, 1, 2, 3.
IX: c, 1, 2, 3.
X: c, 1, 2, 3.
XI: 1, 2, 3.
Telson: 8

The so-called larva III might be mentioned here (Fig. 11). Dorsally a suture can be seen on terg. X demarkating terg. XI without setae, ventrally the segment with its two setae are very well marked. It is important that there are only 2 setae against 6 in the adult—exactly as in Acerentomoidea and different from the numbers in Eosentomoidea.

Abdominal segment VIII (Fig. 12) has a serrated line which may be regarded as the striate band. There is a distinct lid above the mouth of the big abdominal glands, but it is without any distinctive structures. It is different from the "lids" of Eosentomoidea.

The female squama genitalis (Fig. 13) is shaped as a tube, the perigynium continuing in the basal arms; its basal limitation could only be seen indistinctly. The perigynium continues distally in two very weak medial papillae and laterally in two styli

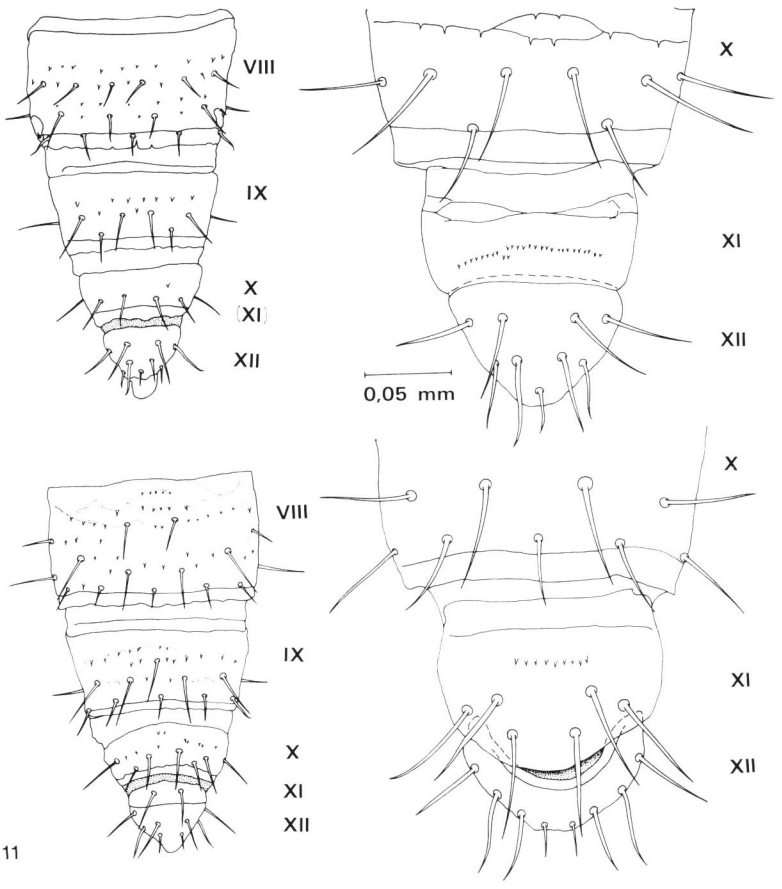


Fig. 11. *Sinentomon erythranum* YIN. Hind part of abdomen of maturus junior (to the left) and adult (to the right) in dorsal (above) and ventral views.

which are narrow at base and apparently tripartite, the acrostylus being surrounded by two spine-like processes of basistylus.

The male squama genitalis (Fig. 14) seems to be rigid, the different parts not retractable into each other. It is different from any other male squama known to me in the loss of setae; no setae are present either dorsally or ventrally. Furthermore the basiperiphallus seems to be divided dorsally in the middle line. Two small setae (?) at the end of acroperiphallus may mark the remnants of side-plates.

Systematic Position

An evaluation of the characters stated above results in the following:

1. The thick cuticle is a highly specialized character involving several other characters.

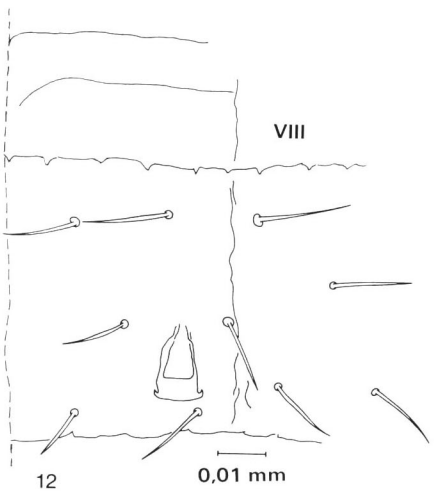
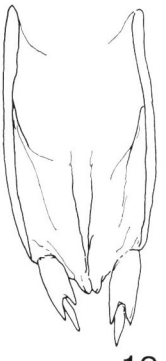
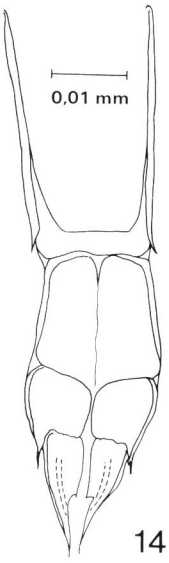


Fig. 12. *Sinentomon erythranum* YIN. Right side of abdominal segment VIII. Dorsal to left.





Figs. 13–14. *Sinentomon erythranum* YIN. —— 13. Female squama genitalis. —— 14. Male squama genitalis.

2. Clypeal apodeme missing. It is present in Eosentomoidea, missing in Acerentomoidea.

3. The "grating" of the pseudoculus is a highly specialized character, perhaps connected with the thick cuticula.

4. The blunt mandible with apical teeth points to Eosentomoidea, but is also characteristic of *Hesperentomon* and —without teeth— of other Protentomidae.

5. The laciniae of the maxilla are pointed as in Acerentomoidea, not hook-shaped as in Eosentomoidea.

6. Galea is fringed as in Eosentomoidea, not pointed as in Acerentomidae.

7. Canal of maxillary gland could not be seen. It *may* be as in Eosentomoidea, a simple tube.

8. Labial palp with end tuft and no sensillae, as in Eosentomoidea.

9. Tracheal system present; spiracles on meso- and metatergum. This is the case in Eosentomoidea, but not in Acerentomoidea where tracheal system is absent. A close inspection reveals, however, that whereas the spiracles in all species of Eosentomoidea are astonishingly alike, those of *Sinentomon* are quite different (see the figures). I deduce from this that the tracheal system in *Sinentomon* is an innovation, developed independently of that of Eosentomoidea.

10. The foretarsus with all primary sensillae present and only *c''* added. Thus the sensillae *f 2*, *b'2*, *x*, *y* and *z* which are always found in Eosentomoidea are absent in *Sinentomon*. The sensillae are of different shape and length, not more or less uniform

as is the case in most Protentomidae. Compared with Acerentomoidea the number of setae are augmented by two α-setae and two β-setae, but the position of the setae is the same.

The presence of a sensilla c'' is important since it points to *Hesperentomon*, the only acerentomoid with doubled c'.

11. The claw with empodium and pretarsal seta s is different from both Eosentomoidea and Acerentomidae, but resembles that of some Protentomidae.

12. The claws of middle and hind legs are boat-shaped with a curved spine indicating the beginning of a tunica. This is characteristic for Protentomidae, developing further in Acerentomidae, but it is entirely different from the claw in Eosentomoidea.

13. Abdominal leg I hollow, with vesicle and four setae, legs II–III solid, slender, with two setae of equal length. This is characteristic of Acerentomidae. It should also be pointed out, that in Eosentomoidea the proximal segment of all three legs carries five setae, in Acerentomoidea, if the legs are two-segmented, only four.

14. Striate band probably present as a single line. It is absent in Eosentomoidea, suffers a progressive reduction in Acerentomidae and is present only as a line in Protentomidae.

15. Lid on the mouth of the big abdominal glands well developed as in Acerentomoidea, not a mere opening as in Eosentomoidea, but its shape is different from the known lids, being longer than broad, strongly sclerotized and without distinctive structures.

16. The abdominal chaetotaxy is very richly developed, but still does not exceed the maximal chaetotaxy in Protura if the third row is regarded as the accessory setae become independent and added by a central seta. Telson may provide a distinguishing chaetotaxy: in Eosentomoidea it carries (dorsally + ventrally) 21 setae, in Protentomidae 17 and in Acerentomidae 15. Again *Sinentomon* points to Protentomidae, carrying 17 setae on telson. Stern. XI carries generally four setae less in maturus junior than in the adult: 8–4 in Eosentomoidea, 6–2 or 4–0 in Acerentomoidea; again *Sinentomon* points to the latter, having 6 setae in the adult and 2 in maturus junior. Dorsum and venter are completely fused in abdominal segments VIII–XII which is a highly advanced character, probably connected with the heavy sclerotization.

17. Female squama genitalis without processus sternalis, entirely different from that of Eosentomoidea. Its shape and the presence of papillae points to Acerentomoidea, especially Protentomidae (the two papillae).

18. Male squama genitalis is different from that of Eosentomoidea in the missing side-plates, but is different from all other male squamae known to me in the complete absence of setae.

From this exposition it will be seen that (6) the fringed galea, (7) the canal of maxillary gland (with doubt) and (8) labial palp are in common with Eosentomoidea, besides (9) the presence of spiracles. In the description, however, I hope to have justified the

viewpoint that the spiracles are independently developed in Eosentomoidea and *Sinentomon*.

In common with Acerentomoidea are the following characters: (2) the missing clypeal apodeme, (5) laciniae, (10) setae and sensillae of foretarsus, (11) claw of foretarsus, (12) claws of middle and hind legs, (15) lid on mouth of abdominal glands, (16) chaetotaxy of abdominal sternum XI, (17) female and (18) male squama genitalis.

In common with Acerentomidae is only (13) the solid abdominal legs II and III.

In common especially with Protentomidae are the characters (11) claw of foretarsus, (14) striate band, (16) chaetotaxy of telson, (17) female squama genitalis.

In common especially with *Hesperentomon* within Protentomidae are the characters (4) blunt mandible with teeth and (10) the presence of *c''* in foretarsus.

Characters special to *Sinentomon* are the characters (1) the thick cuticula and in connection with this (3) the grating of pseudoculus, (16) the fusion of tergum and sternum in abdominal segments VIII–XII. Further (15) the shape of the lid on terg. VIII and (18) the missing of setae on male squama genitalis.

Conclusion

In 1963 I tried to follow some "trends" in the evolution of Protura. The result was briefly that Eosentomoidea and Acerentomoidea are widely separated and that *Hesperentomon* is the genus within Acerentomoidea mostly resembling eosentomoids and perhaps giving rise to both Acerentomidae and Protentomidae.

That *Sinentomon* does not belong to Eosentomoidea is evident first of all from the structure of the female squama genitalis. In fact this organ is the most different one among the two suborders. Almost all characters of *Sinentomon* point to Acerentomoidea, many of them to Protentomidae and then quite especially to *Hesperentomon*.

In my survey of *Hesperentomon* characters (1963, p. 296, ff.) I mentioned "the labile character of the third abdominal appendage"; this "lability" may be said to be extended to the second abdominal appendage in *Sinentomon*. Further the mouthparts: compared with *Hesperentomon, Sinentomon* has retained the "fingers" of galea, but attained pointed laciniae. The doubled sensilla *c'* is found in one species of *Eosentomon*, but in Acerentomoidea only in *Hesperentomon*. The shape and different length of the foretarsal sensillae in *Hesperentomon* is also found in *Sinentomon*, but the shape of empodium and pretarsal seta *s* is different. The shape of the striate band connects the two genera, but the "lid" is different. The shape of the female squama genitalis connects the two genera against the other Protentomidae.

I might conclude, therefore, that *Sinentomon* is a protentomid with close relation to *Hesperentomon* and in so far "archaic", but with so many specialized characters (the strong cuticula, spiracles, two pairs of highly reduced abdominal legs, augmentation of setae on foretarsus, emancipation of the accessory setae on thorax–abdomen, reduction of setae on male squama genitalis) that it must be regarded as a highly specialized form.

Abstract

A re-examination and re-evaluation of the aberrant Chinese Proturan *Sinentomon erythranum* YIN, 1965, revealed that it does not belong to Eosentomoidea, but is a true acerentomoid of the family Protentomidae. It is most closely related to *Hesperentomon* which may be regarded as the most primitive genus within Acerentomoidea, but has so many special characters—i. e. its very strong sclerotization and the characters resulting from this—that it must be regarded as a highly specialized form. The presence of spiracles must be an innovation, independent of the tracheal system of Eosentomoidea.

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